STUDY ON SPIDERS (PARTICULARLY REFERRING TO GRASS-SPIDERS) TO PREY UPON FALL-WEB WORMS (HYPHANTRIA CUNEA DRURY)

Izumi KAYASHIMA

Biological Laboratory, Kunitachi Ongaku Daigaku, Tokyo

I Introduction

The damage by fall-web worms (Hyphantria cunea Drury) is now a problem of Japan as a whole. According to the survey made by the Ministry of Agriculture and Foresty in August 1966, the infestation of this worm has now spread over 19 prefectures such as Tokyo, and those from Akita in the north to Hyogo in the south and caused a serious damage.

It is considered that this insect has been brought into Japan from the American Continent sticking to imported goods. It was 1948 when the infestation has become conspicuous. In Tokyo and Kanagawa prefecture, road-side trees and garden trees were heavily infested and then, the infestation was spread over other prefectures.

This insect is omnivorous but it does not attack conifers such as pines and Japanese ceder but it prefers broadleaf trees.

Its infestation is particularly significant in mulberry, cherry, willow and plane trees. Its damage on vegetable is variable according to areas and in Tokyo area, it rarely lays eggs on vegetables and the larva which ate up trees attacks egg plant, tomato and Indian corn and its annual damage is enormous.

There are two ways of control: the one is the spray of chemicals and the other is a primitive control as to pick up the infested leaves together with young larvae and burn them.

The chemicals now being used are emulsion of DEP and DDVP.

The larvae produce threads and make nets in which they live in group and their period of prey is longer than that of other insects.

For this reason, the spray of chemical seems to be not so much effective. Some larvae are resistant to chemicals and also it is found that the chemicals are injurious to men and animals. In this sense, we can no longer depend upon such way of control. In case of mulberry tree, when chemical-sprayed leaves are given to silk worms, there are unfavorable influences upon them.

Therefore, other control measures than the chemical spray should be taken as soon as possible.

The introduced injurious insects cause serious damage in their invaded area which may be attributed to the absence of biological control. The fall-web worm is one of these insects and no biological control is found up to now.

The study in this field is now under way. One of these studies is undertaken at the sericulture experimental station in Kanagawa Prefecture where the experiment has been started by means of virus but such experiment involves much difficulties and much time seems to be needed to put the experiment into practice.

The writer has worked on the control of this injurious insect by means of spiders and found that spiders have much effects upon this insect. The fundamental study started in June 1964 and is still continued today. Fortunately, Toyoda district, Hino City, Tokyo, where the writer resides is close to Hachioji City which is well known for silk textile production center. The residence of the writer locates among mulberry farms.

Once this insect infests in the mulberry farm, young and old larvae come into the house and become pupae in every corner of the house. Particularly, for these two or three years, owing to the fact that house owners neglect the maintenance of their own properties because these houses are to be purchasd sooner or later by the local government under the city planning project, the infestation is becoming more and more serious.

Based on these abundant materials, the writer worked on the study for 3 years by the following ways. The result of the study seems to be encouraging as stated below.

Before getting in touch with the main subject, the writer wishes to extend his thanks to Dr. Kyozo Yasumatsu, professor of Faculty of Agriculture of Kyushu University who gives the writer instruction on the study of biological control, Dr. Kyukichi Kishida, Dr. Toshio Uemura and Dr. Takeo Yaginuma who help the writer in studying spiders and meanwhile, the writer's appreciation should be given to Miss Natsuko Tsukiji, member of the writer's family as Mrs. Makiko Kayashima, Shin, Ko and Mitsuko.

It is also noted that a part of the expenses spent for this study is paid by the subsidy for scientific research of the Ministry of Education for the fiscal year of 1966.

II Method of Study

1. Period of Study

For 1964 From 1 June 1964 to 10 September 1964
For 1965 From 1 June 1965 to 10 September 1965
For 1966 From 1 June 1966 to 10 September 1966

Since the relationship between the injurious insect and spiders is quite conspicuous in the above period, these 102 days were spent for study.

2. Establishment of mulberry farm for study and the condition of the experimental mulberry farm.

In consultation with the owner, as shown in Fig. 1, two sites are selected for study.

The A area is 12.6 a and 157 mulberry trees are planted and the B area is 14.04a and 201 mulberry trees are planted. As stated above, these mulberry farms were placed under poor management and fall-web worms were seriously prevailing. Thus, the officials of Hino City Office sprayed DEP emulsion two times respectively as 15 July and 13 August 1964, 17 July and 11 August 1965 and 10 July and 14 August 1966. However, no effect of chemicals was found in the farm and serious damages were still existed. It was fortunate to find out the resistance of spiders inhabited in the farm to the chemicals.

3. Matters to study

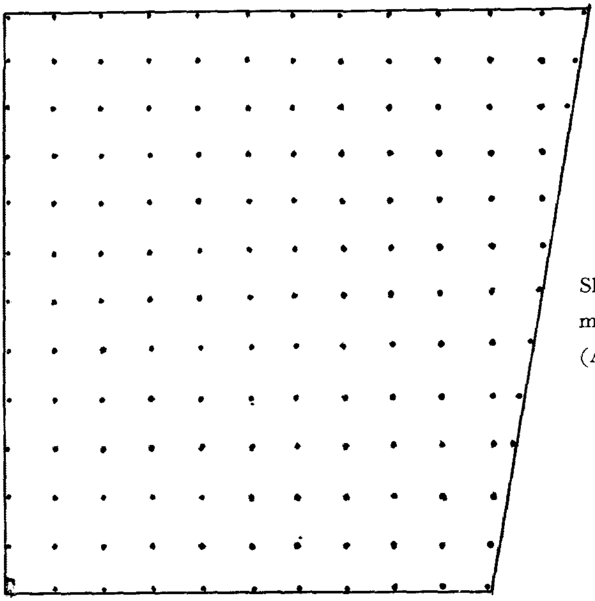
i) Fundamental study

a. Study on species of spiders in the mulberry farm in question. In order to know the species of spiders inhabited in the mulberry farm in question. the study was made every two days and the list of spiders found there was prepared for throughout the three years of study.

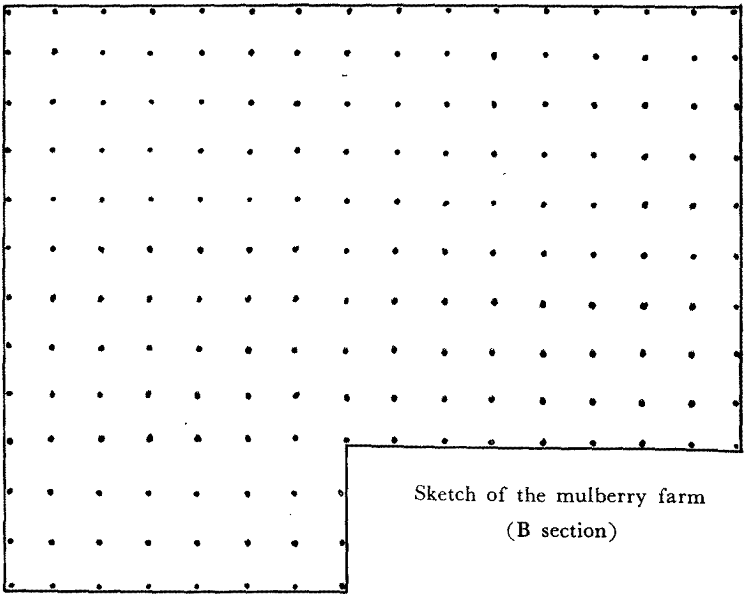
b. Study on spiders to prey upon the the fall-web worms. The writer made the patrol on the day when the spiders were preying upon the worms or they were on the net. The initial program was to make the study at 6—7 o'clock in the morning and 4—5 o'clock in the afternoon one hour every day but circumstances prevented the regular work. However, two studies were made without fail. It was quite rare to find out spiders preying noxious worm in two hours of two studies.

For reference, the writer took the food residue in the nest or the piece of food fallen from the nest.

Fig. 1.



Sketch of the
mulberry farm
(A section)



Sketch of the mulberry farm
(B section)

ii) Study on the application

(Study on how the grass-spiders are helpful for control of the noxious worms).

a. Study on the living condition of the grass-spiders in the experimental mulberry farm. Once the grass-spiders make their nests, they live there until they mature. Except for special reason, they do not move elsewhere. The nest made in the mulberry farm is smaller than that made in other place and they can not spread their sheet-like net which is peculiar to the spider. This is due to the fact that the mulberry tree grows by sprouting with few branches and the height is low. Therefore, they make nest on five or six leaves skillfully.

(See Plate 1 Figs. 2, 4 and 5).

Because two chemical sprays were made every year during the study, the location of nesting was somewhat changed. The study period was divided into the former period, the middle period and the latter period and the sketch of nesting of grass-spiders in the mulberry farm was prepared.

b. Study on how much the grass-spiders prey upon fall-web worms.

i) How much do they prey upon the worms in natural condition. The study was made how the grass-spiders catch the injurious worms and how much do they eat or how much injurious worms were trapped by spiders' net. The observations were noted in the field-note every time and summarised.

ii) Larvae and imagos of fall-web worms were given by man and the study was made how much do grass-spiders eat.

Injurious worms were fallen on the nests of grass-spiders in the following manner and the same experiment was repeated. (This experiment was made only in 1966).

Case of larvae

How grass-spiders prey upon worms was studied as 20 larvae of less than 1 cm long, 10 larvae of 1 cm — 2 cm, 3 larvae of 2 cm — 4 cm and 1 larvae of more than 4 cm long were given to every spider.

Case of imago

Grass-spiders' preying upon was observed by giving one imago of the worm.

In either of larvae or imago, 10 experiments were made on each item. Although the experiments and the number of testing individuals were considered to be few, the tendency seems to be found.

Ⅲ Results of Study

i) Fundamental Study

a) Study of spiders in the mulberry farm in question.

During the three years' study, the following spiders were collected every year.

Table 1. List of the spiders which were found in the mulberry farm.

1. Dictyna foliicola Boes. et. Str.
2. Uloborus varians Boes. et. Str.
3. Theridion tepidariorum C. Koch
4. Theridion japonicum Boes. et. Str.
5. Araneus fuscocoloratus Boes. et. Str.
6. Araneus pentagrammicus (Karsch)
7. Araneus ventricosus macacus Uyemura
8. Neoscona scylla (Karsch)
9. Neoscona doenitzi (Boes. et. Str.)
10. Neoscona scylloides (Boes. et. Str.)
11. Argiope amoena L. Koch
12. Argiope bruennichii (Scopoli)
13. Nephila clavata L. Koch
14. Cyclosa atrata Boes. et. Str.
15. Leucauge magnifica Yaginuma
16. Tetragnatha praedonia L. Koch
17. Dolomedes saganus Boes. et. Str.
18. Pisaura lama Boes. et. Str.
19. Lycosa T-insignita Boes. et. Str.
20. Lycosa pseudoannulata (Boes. et. Str.)
21. Agelena opulenta L. Koch
22. Agelena limbata Thorell
23. Misumenops tricuspidatus (Fabricius)
24. Thomisus labefactus Karsch

25. Xysticus croceus Fox
36. Hasarius doenitzi Karsch
27. Carrhotus detritus Boes. et. Str•
28. Silerella vittata (Karsch)
29, Rhene atrata (Karsch)
30. Plexippus paykulli (Adouin)
31. Myrmarachne japonica (Karsch)
32. Gnaphosa kompirensis Boes. et. Str.

The above 32 species of spiders are living in the mulberry farm during the growing season and collection could be done regularly every year. Particularly, beautiful nets made by *Argiope amoena, Argiope bruennichii, Nephila clavata* are found everywhere in the mulberry farm and nests of the grass-spiders are shining under the morning sun and we were surprised at the numerous number of spiders in the farm. Beside the above, nearly 30 species of spiders which were collected only only one time are excluded from the above list as they are scarcely found in the mulberry farm.

b) Study on spiders which prey upon the fall-web worms.

While 32 species of spiders were found in the mulberry farm, it was observed that the following 16 species were preying upon fall-web worms.

Table 2. List of spiders which prey upon fall-web worms in the mulberry farm.

1. Dictyna foliicola Boes. et. Str.
2. Theridion tepidariorum C. Koch
3. Araneus pentagrammicus (Karsch)
4. Araneus ventricosus macacus Uyemura
5. Neoscona scylloides (Boes. et. Str.)
6. Argiope amoena L. Koch
7. Argiope bruennichii. (Scopoli)
8. Nephila clavata L. Koch
9. Cyclosa atrata Boes. et. Str.
10. Pisaura lama Boes. et. Str.
11. Lycosa T-insignita Boes. et. Str.
12. Agelena opulenta L. Koch
13. Agelena limbata Thorell

14. Misumenops tricuspidatus (Fabricius)
15. Hasarius doenitzi Karsch
16. Plexippus paykulli (Adouin)

Of the above spiders, those which prey upon at the most are grass-spiders and during the period of study, they ate pupae or imagos. *Dictyna foliicola* was eating quite many stage larvae. *Lycosa T-insignita* eats larvae fallen on the ground and also preys upon imagos. *Theridion tepidariorum* preys upon both larvae and imagos.

Larvae and imagos of this worm are often trapped by nets of *Araneus ventricosus macacus*, *Neoscona scyllodes*, *Argiope amoena*, *Argiope bruennichii*, *Nephila clavata* and *Cyclosa atrata* which spread circular nets vertically against ground. Particularly, *Cyclosa atrata* is a small spider and it was observed that young larva was trapped in the net. *Pisaura lama* is a species having many individuals, but the writer observed that only one spider preyed on a larva.

Misumenops tricuspidatus preys upon the larva of early stage but when the larva becomes large, the spider runs away. Both *Hasarius doenitzi* and *Plexippus paykulli* caught imagos. The above descriptions are tabulated in next page.

ii) Study on the application.

(Study on how the grass-spiders are helpful for control of this injurious worms.)

a) Study on the condition of living in the mulberry farm question. A sketch of nesting of grass-spiders in the mulberry farm in question is as follows. The sketch of the above is tabulated in ten page.

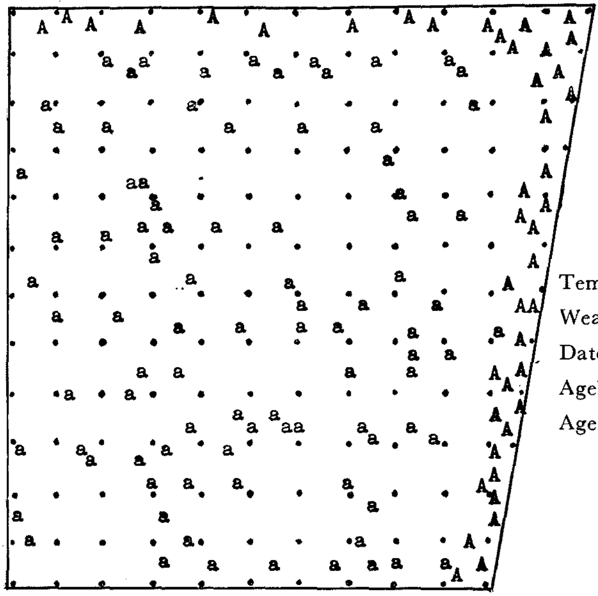
Table 3. List of the spiders which prey upon fall-web worms in the mulberry-farm. (Preying season and stagi of the fall-web worm)

Month		June			July			Aug.			Sep.
Period of ten days		1 10	11 20	21 30	1 10	11 20	21 31	1 10	11 20	21 31	1 10
Species	Year										
1. Dictyna foliicola	1964					×			×		
	1965					×			×		
	1966						×		×		
2. Theridion tepidariorum	1964										
	1965			*		×					
	1966								×		
3. Araneus pentagrammicus	1964										
	1965					×					
	1966						×				
4. Araneus ventricosus macacus	1964			*			*	*			
	1965										
	1966			*							
5. Neoscona scylloides	1964										
	1965						*				
	1966										
6. Argiope amoena	1964										
	1965			*							
	1966										
7. Argiope bruennichii	1964							*	*		
	1965							*	*		
	1966							*			
8. Nephila clavata	1964										
	1965							*	×		
	1966								×		
9. Cyclosa atrata	1964				×						
	1965										
	1966									×	
10. Pisaura lama	1964										
	1965				×						
	1966										
11. Lycosa T-insignita	1964							×		×	
	1965				×			*			
	1966								*		
12. Agelena opulenta	1964				×	×	×	*	*	*	
	1965				×	×		*	*	*	
	1966				×	×	×		*	*	
13. Agelena limbata	1964	*	*	×	×	×	×	×*	*		
	1965	*	*	×	×	×	×	×*	*		
	1966	*	*	*	×	×	×	×	×*	*	
14. Misumenops tricuspidatus	1964			×							
	1965										
	1966				×				×		
15. Hasarius doenitzi	1964										
	1965							*			
	1966								*		
16. Plexippus paykulli	1964										
	1965		*						*		
	1966										

* ····················Imago stage　　× ····················Larval stage

Fig 2

A section

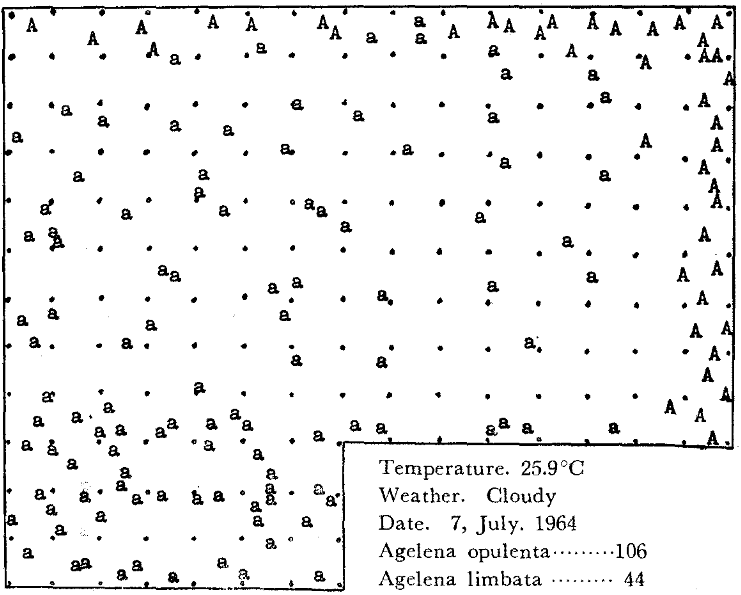


A.······Agelena limbata

a.······Agelena opulenta

Temperature. 25.9°C
Weather. Cloudy
Date. 7, July. 1964
Agelena opulenta······89
Agelena limbata ······44

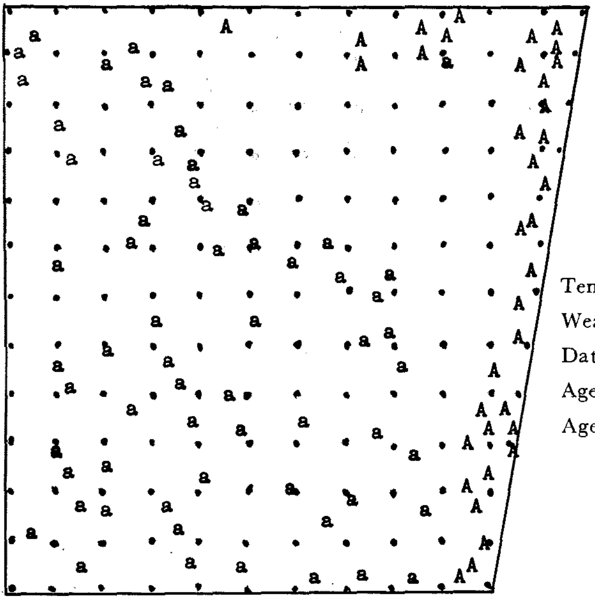
B section



Temperature. 25.9°C
Weather. Cloudy
Date. 7, July. 1964
Agelena opulenta·········106
Agelena limbata ········· 44

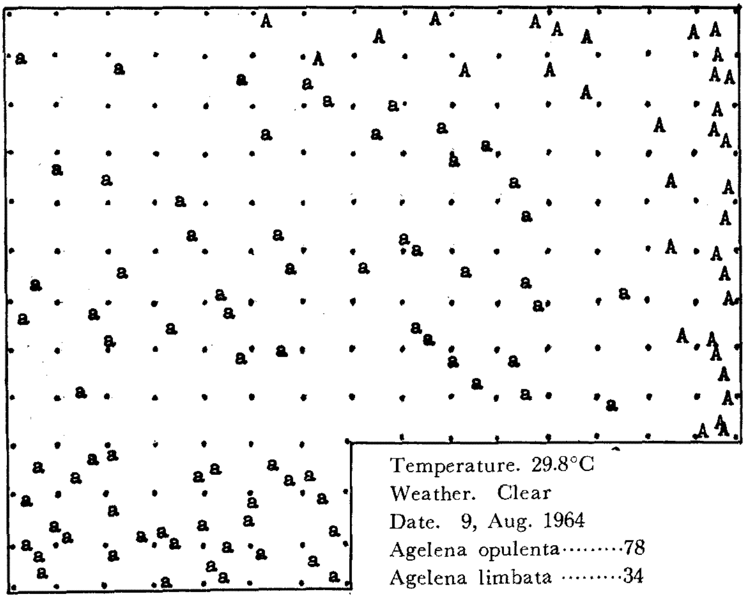
Fig 3

A section



Temperature. 29.8°C
Weather. Clear
Date. 9, Aug. 1964
Agelena opulenta ……61
Agelena limbata ……36

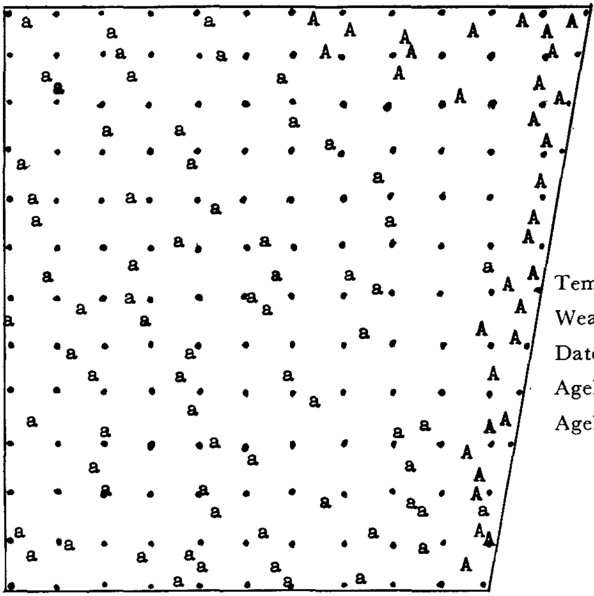
B section



Temperature. 29.8°C
Weather. Clear
Date. 9, Aug. 1964
Agelena opulenta ………78
Agelena limbata ………34

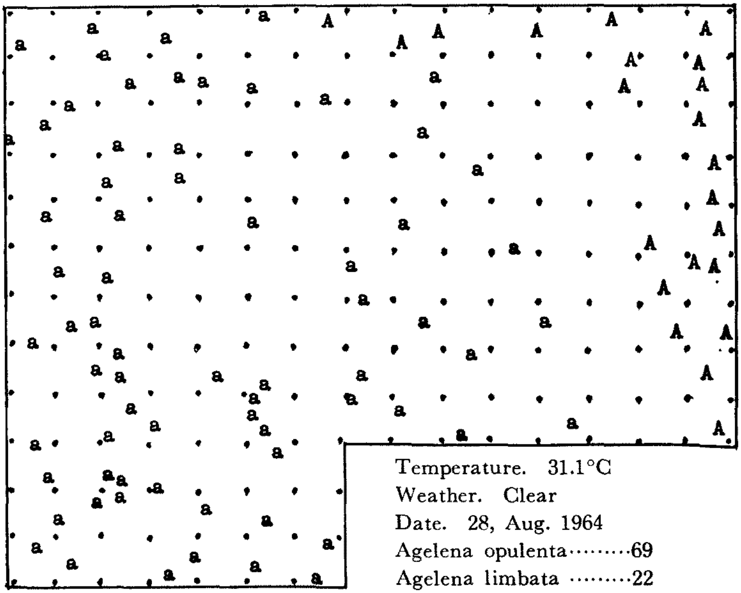
Fig 4

A section



Temperature. 31.1°C
Weather. Clear
Date. 28, Aug. 1964
Agelena opulenta……71
Agelena limbata ……33

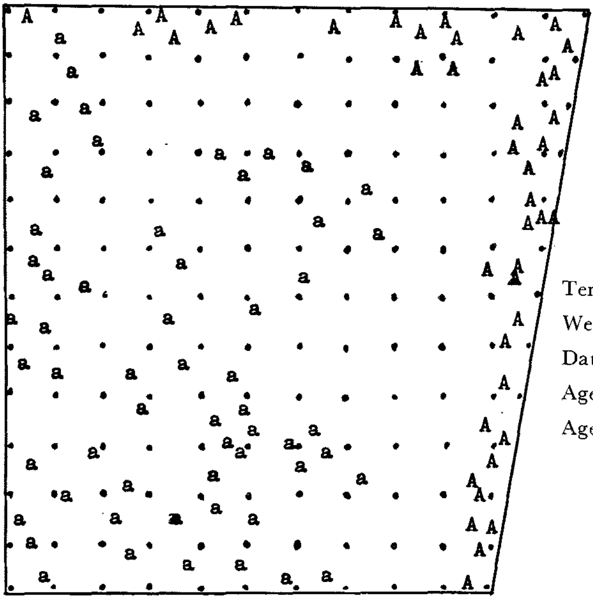
B section



Temperature. 31.1°C
Weather. Clear
Date. 28, Aug. 1964
Agelena opulenta………69
Agelena limbata ………22

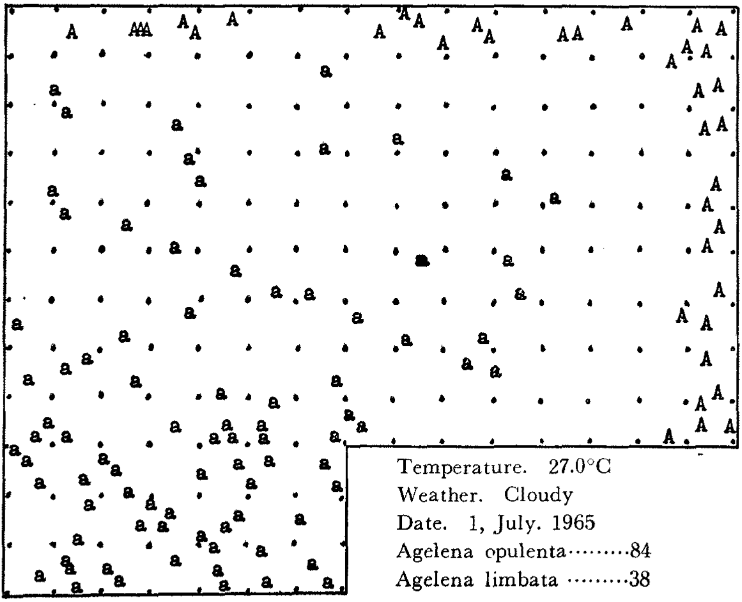
Fig 5

A section



Temperature. 27.0°C
Weather. Cloudy
Date. 1, July. 1965
Agelena opulenta ……57
Agelena limbata ……42

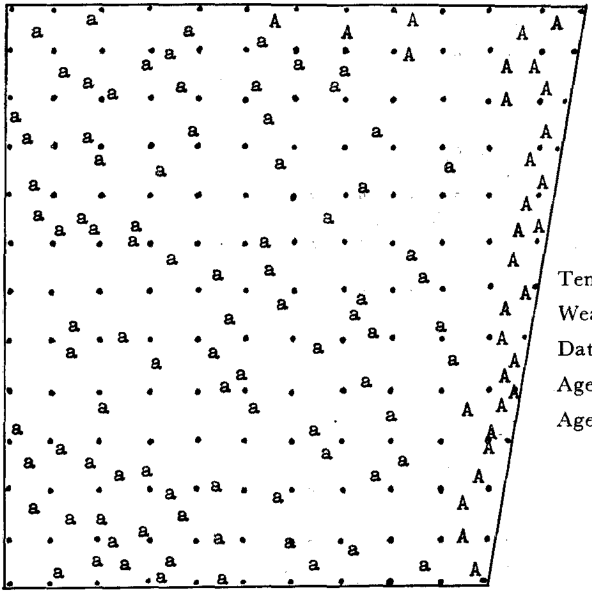
B section



Temperature. 27.0°C
Weather. Cloudy
Date. 1, July. 1965
Agelena opulenta………84
Agelena limbata ………38

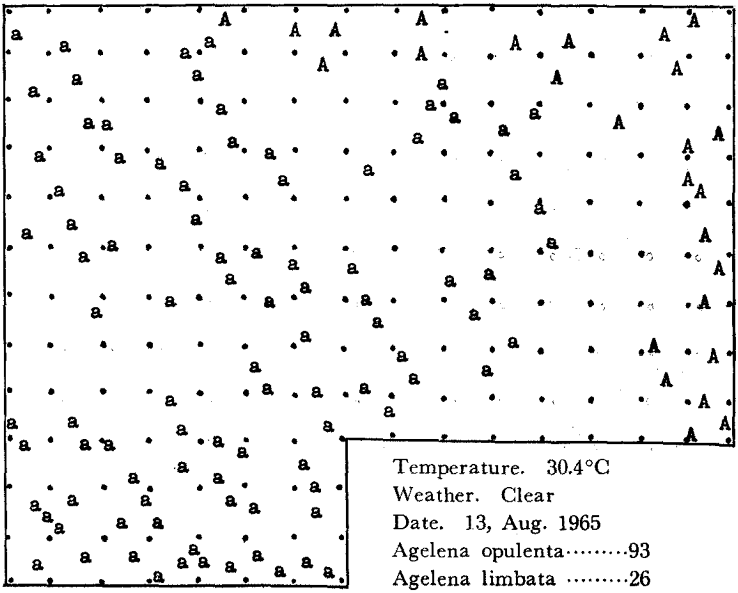
Fig 6

A section



Temperature. 30.4°C
Weather. Clear
Date. 13, Aug. 1965
Agelena opulenta ……87
Agelena limbata ……31

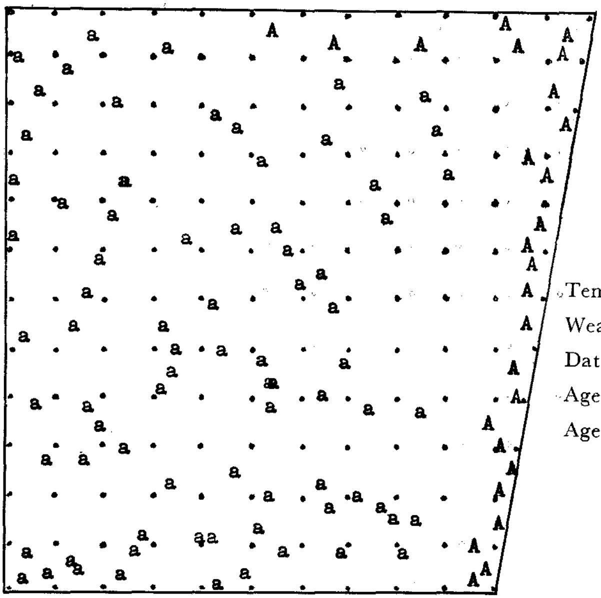
B section



Temperature. 30.4°C
Weather. Clear
Date. 13, Aug. 1965
Agelena opulenta………93
Agelena limbata ………26

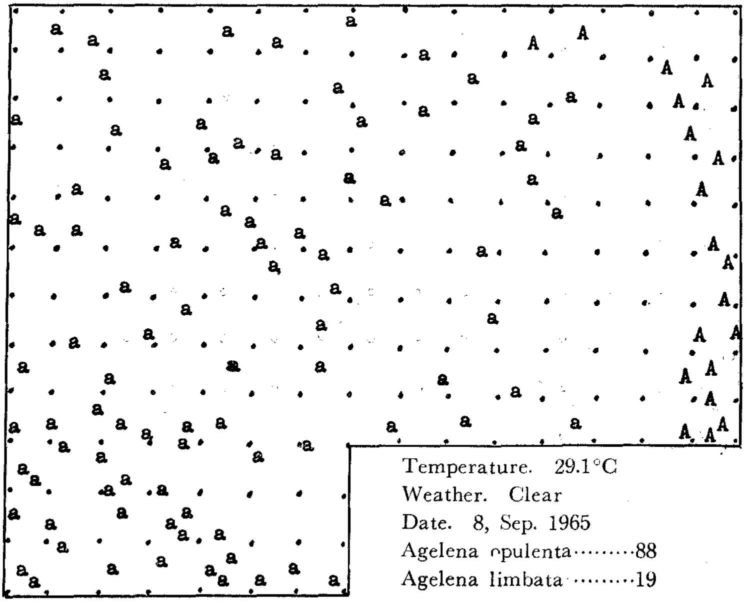
Fig 7

A section



Temperature. 29.1°C
Weather. Clear
Date. 8, Sep. 1965
Agelena opulenta ······79
Agelena limbata ······26

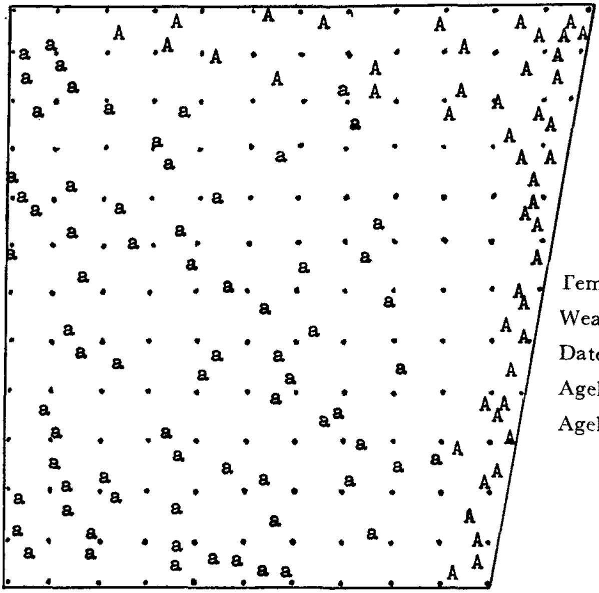
B section



Temperature. 29.1°C
Weather. Clear
Date. 8, Sep. 1965
Agelena opulenta·········88
Agelena limbata ·········19

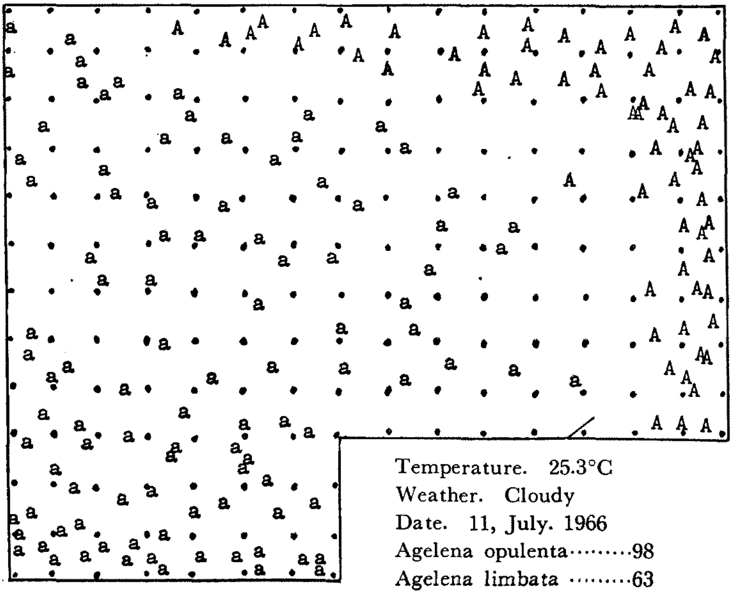
Fig 8

A section



Temperature. 25.3°C
Weather. Cloudy
Date. 11, July. 1966
Agelena opulenta……71
Agelena limbata ……49

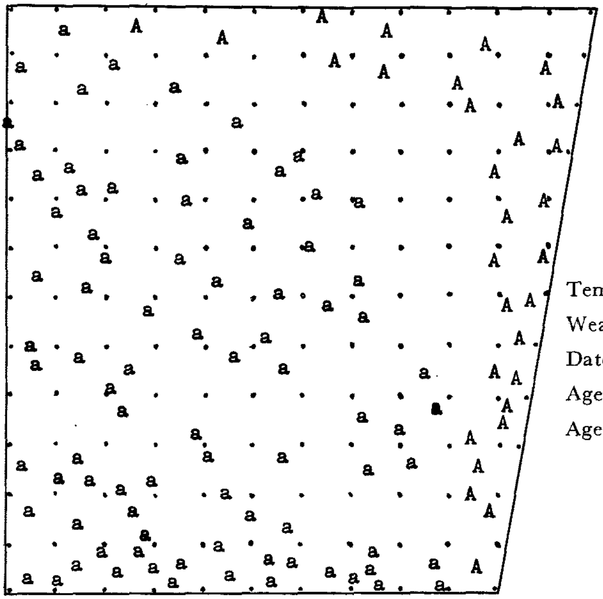
B section



Temperature. 25.3°C
Weather. Cloudy
Date. 11, July. 1966
Agelena opulenta………98
Agelena limbata ………63

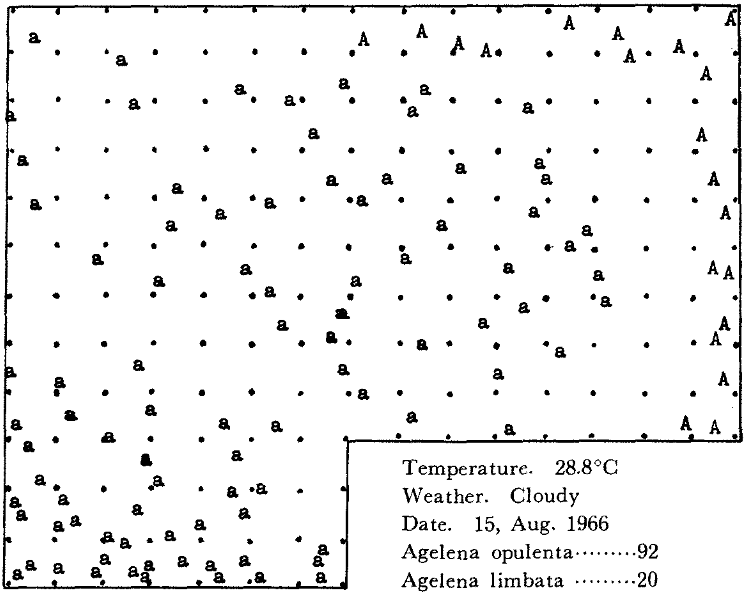
Fig 9

A section



Temperature. 28.8°C
Weather. Cloudy
Date. 15, Aug. 1966
Agelena opulenta······83
Agelena limbata ······30

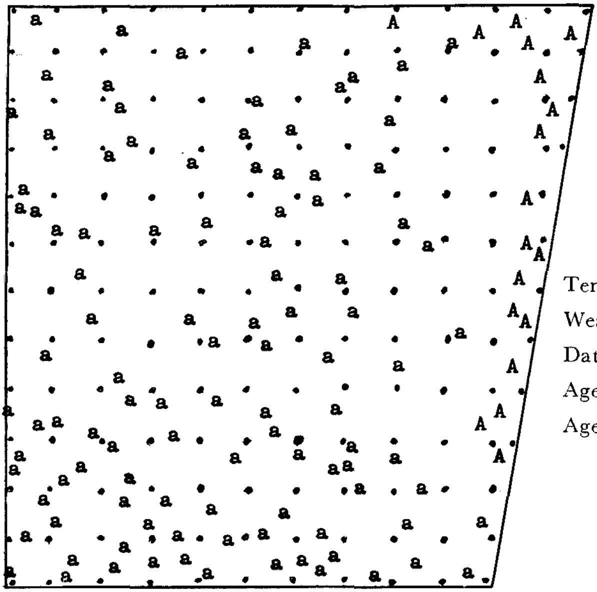
B section



Temperature. 28.8°C
Weather. Cloudy
Date. 15, Aug. 1966
Agelena opulenta·········92
Agelena limbata ·········20

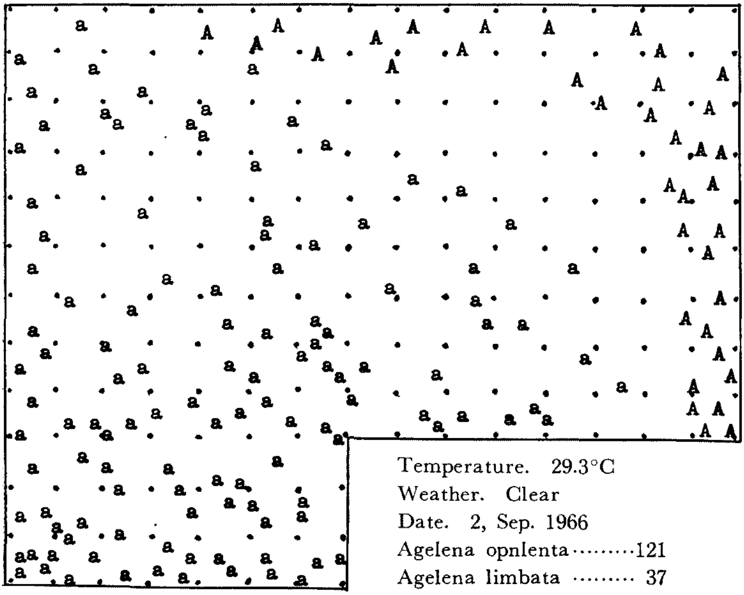
Fig 10

A section



Temperature. 29.3°C
Weather. Clear
Date. 2, Sep. 1966
Agelena opulenta···108
Agelena limbata ··· 18

B section



Temperature. 29.3°C
Weather. Clear
Date. 2, Sep. 1966
Agelena opnlenta·········121
Agelena limbata ········· 37

Table 4. Number of spiders found in the mulberry farm.

Species	a b c	1964				1965				1966			
		1	2	3	Total	1	2	3	Total	1	2	3	Total
Agelena opulenta	A section	89	61	71	221	57	87	79	223	71	83	108	262
	B section	106	78	69	253	84	93	88	265	98	92	121	311
	Total	195	139	140	474	141	180	167	488	169	175	229	573
Agelena limbata	A section	44	36	33	133	42	31	26	99	49	30	18	97
	B section	44	34	22	100	38	26	19	83	63	20	37	120
	Total	88	70	55	233	80	57	45	182	112	50	55	217

a …………… Year
b …………… No. of the observations
c …………… Mulberry-farm

From the above table, the followings can be said. In each year, almost the same number of grass-spiders inhabited. *Agelena opulenta* is more in individual than *Agelena limbata* and lived almost all areas but *Agelena limbata* was found only north and south sides. This is due to the fact north and south sides are connected to the brush and *Agelena limbata* lived come into the mulberry farm. *A. opulenta* is slower in growth than *A. limbata* and it becomes adult in one and a half month, from late August to middle September. Although some removal of nests of grass-spiders caused by agricultural chemicals was observed, no reduction of individuals was found. This fact seems to be due to the fact that when agricultural chemicals are sprayed, grass-siders escape into the shelter (they make tunnel-like nest connecting to sheet-nest) and they are free from such chemicals. Every year, between first and second times, or second and third time, there was spray of agricultural chemicals but there had been no change in the number of individuals at all as stated in the above.

b) Study on how much the grass-spiders prey upon fall-web worms.

i) Study in natural condition.

Study was made on how much grass-spiders prey upon fall-web worms which is tabulated as follows.

Table 5 Number of fall-web worms eaten by grass-spiders in the mulberry-farm (Larval stage)

Month Date of observations Year Species		June									
		1	4	7	10	13	16	19	22	25	28
Agelena opulenta	1964										
	1965										
	1966										
Agelena limbata	1964									1	40
	1965										62
	1966										

Month Date of observations Year Species		July									
		1	4	7	10	13	16	19	22	25	28
Agelena opulenta	1964				9	16	10	28	18		
	1965				4	17	29	12			
	1966				2	14	19		11		
Agelena limbata	1964	7	31	19	6	19	35	17			
	1965	13	19	16	8	10	21	29			
	1966	9	14	24	1	5	8	12	3		

Month Date of observations Year Species		Angust										
		3	6	9	12	15	18	21	24	27	30	Total
Agelena opulenta	1964	9	15	8	18	19	17	51	86	23		327
	1965	5	27	16	12	20	22	14	13	19		210
	1966	8	13	14	4	26	11	15	22			159
Agelena limbata	1964	13	21	17	7	2						235
	1965	20	15	9	2							224
	1966	16	18	14	5							129

Table 6 Number of fall-web worms eaten by grass-spiders in the mulberry farm (Imago stage)

Month Date of observations Year Species		June									
		1	4	7	10	13	16	19	22	25	28
Agelena opulenta	1964										
	1965										
	1966										
Agelena limbata	1964	3	16		11	13		15			
	1965		4	18	1	17	5	2			
	1966		1	1	8	1	7	1	3	1	

Month Date of observations Year Species		August										
		3	6	9	12	15	18	21	24	27	30	Total
Agelena opulenta	1964		12	6	7	11	6	14				56
	1965			5	4	13	1	3	1	8		35
	1966				3	2	9	55	4	7	12	32
Agelena limbata	1964			14	21	5						98
	1965				2	18						67
	1966				1	2	1					25

Referring to the above table, *A. opulenta* is too young and too small from late June to early July to prey upon larvae of injurious worms. He is running away and does not prey upon but larvae which were born in the second time, prey upon very much. When *A. limbata* begins to disappear, *A. opulenta* is still in adult and active.

A. limbata preys upon well worms since its first emergence in late June. Although the number of individuals of *A. limbata* is fewer than that of *A. opulenta* the number of worms to prey upon is more. When the number of worms caught by one spider was studied, it was higher than the former species. By years, the number of worms preyed upon is gradually on the decrease. It is because of the fact that the damage in the mulberry farm in question was less than before.

In the table, it is found that the emergence of the imago of this worm is the most in early and middle June, and early and middle August and according to the growth, a few of them are a little later in their emergence than the above. *A. opulenta* is too young to prey upon at the first emergence of the imago of the worm. However, it preys upon those of the second emergence more than *A. limbata* does. *A. limbata* preys upon both the first and second emergences of imagos but it preys upon only those of the second emergence of imagos in middle August only and as *A. limbata* become older late August, the rate of prey is much reduced.

ii) Study on how much grass-spiders prey upon larvae and imagos of fall-web worm when the latter was given by man.

A. *Case of larva*

a. Experiment on larvae less than 1 cm in length.

When the larvae of fall-web worms are less than 1 cm in length, they live in aggregation. When 20 fall-web worms are fallen on the nest of grass-spiders, these 20 worms form a mass. This is easy to prey for spiders and the preying at this time is shown in Table 7.

b. Experiment on larvae 1 cm - 2 cm in length.

Even when the larvae are 1 cm - 2 cm in length, they live in aggregation. However, when 10 larvae are fallen on the spiders' nests, different from the above case, they run around separately and individually. Then, we can observe that spiders chase larvae and walk around and trap them by thread. How to prey is showm in Table 8.

c. Experiment on larvae 2 cm - 4 cm in length.

The larvae at this period are moving from the aggregation to the independent life and the experiment was made by dropping 3 worms on the nests of spiders. The result of this experiment is shown in Table 9.

d. Experiment on larvae more than 4 cm in length.

When the length exceeds 4 cm, many of them run away, cutting threads of nests of spiders.

Some spiders went to prey upon but they could not wind up worms well. So that many spiders hesitated to prey. The result of this experiment is shown in Table 10.

Table 7. Experiment of Grass-spiders on how to prey upon fall-web worms.
Size of larvae used for experiment: under 1 cm.

Species of spiders	Number of experiment	Same day	Following day	Run away
Agelena opulenta	1	8	—	12
	2	7	1	12
	3	11	1	8
	4	10	1	9
	5	8	2	10
	6	6	2	12
	7	3	3	14
	8	8	1	11
	9	7	2	11
	10	4	1	15
Agelena limbata	1	18	—	2
	2	13	4	3
	3	16	1	3
	4	12	5	3
	5	13	1	6
	6	11	2	7
	7	18	1	1
	8	16	2	2
	9	15	1	4
	10	16	1	3

Numbers of larvae used for experiment: 20

Date of experiment: 3rd. August, 1966

Table 8. Experiment of grass-spiders on how to prey upon fall-web worms.
Size of larvae used for experiment: 1 cm — 2 cm.

Species of spiders	Number of experiment	Same day	Following day	Run away
Agelena opulenta	1	6	1	3
	2	3	—	7
	3	3	2	5
	4	3	1	6
	5	2	—	8
	6	4	1	5
	7	4	4	2
	8	6	1	3
	9	5	3	2
	10	4	1	5
Agelena limbata	1	8	2	—
	2	7	3	—
	3	5	3	2
	4	7	1	2
	5	4	1	5
	6	6	—	4
	7	3	1	6
	8	6	1	3
	9	7	—	3
	10	8	1	1

Numbers of larvae used for experiment: 10

Date of experiment: 7th. August, 1966

Table 9. Experiment of grass-spiders on how to prey upon fall-web worms.
Size of larvae used for experiment: 2 cm — 4 cm.

Species of spiders	Number of experiment	Same day	Following day	Run away
Agelena opulenta	1	2	1	—
	2	—	—	3
	3	2	1	—
	4	—	—	3
	5	1	1	1
	6	—	—	3
	7	—	—	3
	8	—	—	3
	9	1	1	1
	10	1	—	2
Agelena limbata	1	2	—	1
	2	1	1	1
	3	1	1	1
	4	2	1	—
	5	—	—	3
	6	—	—	3
	7	2	1	—
	8	—	—	3
	9	—	—	3
	10	2	1	3

Numbers of larvae used for experiment: 3

Date of experiment: 14th. August, 1966

Table 10. Experiment of grass-spiders on how to prey upon fall-web worms. Size of larvae used for experiment: 4 cm over.

Species of spiders	Number of experiment	Same day	Following day	Run away
Agelena opulenta	1	—	—	1
	2	—	—	1
	3	—	—	1
	4	—	—	1
	5	1	—	—
	6	—	—	1
	7	—	—	1
	8	—	—	1
	9	—	—	1
	10	—	—	1
Agelena limbata	1	1	—	—
	2	—	—	1
	3	—	—	1
	4	—	—	1
	5	1	—	—
	6	—	—	1
	7	—	—	1
	8	—	—	1
	9	—	—	—
	10	—	—	1

Number of larvae used for experiment: 1

Date of experiment: 19th. August, 1966

Considering the above 4 tables, *Agelena limbata* preys upon larva more than *Agelena opulenta.* However, the ratio of prey of both species is higher in smaller larva than in larger ones. When the length exceeds 4 cm, they can hardly prey and it was found that in the future, more study was needed on larva less than 4 cm long. Regarding the speed of preying one larva of grass-spiders, it ate up in 5 min. in case of 1 cm long but when the length exceeds 2 cm, many of them could not eat up even in 30 min.

B. *Case of imago*

The study was made on the prey by putting one imago on the nest of grass-spiders. When an imago is put on the nest, the spider comes in and walks around the imago and spread the thread and it often bites and injects the poison. It takes some time for *Agelena opulenta* to take one imago to the shelter but for *Agelena limbata,* it carries the imago in 5 min. However, those tested at night almost fled away. This imago has a nocturnal habit and cuts off the thread of grass-spider's nest. The behavoir of these grass-spiders at night is quick in action and when the imago is put near the spider, the latter catches the former instantly. The result of this experiment is shown in Table 11.

As stated in the above table, 50% of imagos were eaten by *Agelena opulenta* and 50% ran away. In case of *Agelena limbata,* 60% were eaten and 40% ran away.

IV **Observations**

From the above three years study, we can find some number of spiders prey upon these injurious worms (at present 16 species) but on species of spiders is found which is beneficial as biological control in natural condition. It is our success to find out grass-spiders which are quite useful to control if propagated spiders are liberated in the infested area. The reason for this is: (1) grass-spiders are stationary in nature: (2) because the nest is spread in sheet, larvae are fallen on these sheet nets and trapped: (3) in order to support this sheet-like net, many lengthwise thread and slopewise thread are ramified in which imagos are often trapped: (4) of grass-spiders, the maturity of *Agelena opulenta* is later 1 ½ months than *A. limbata.* During the period of emergence of such noxious worms, this

Table 11. Experiment of grass-spiders on how to preying upon fall-web worms. (Imago stage)

Species of spiders	Number of experiment	Same day	Following day	Run away
Agelena opulenta	1	1	—	—
	2	1	—	—
	3	—	—	1
	4	—	—	1
	5	—	—	1
	6	1	—	—
	7	1	—	—
	8	—	—	1
	9	1	—	—
	10	—	—	1
Agelena limbata	1	1	—	—
	2	1	—	—
	3	1	—	—
	4	1	—	—
	5	1	—	—
	6	—	—	1
	7	—	—	1
	8	—	—	1
	9	1	—	—
	10	—	—	1

Number of imagos used for experiment: 1.

Date of experiment: lst. August, 1966

spider lives and preys upon larvae and imagos: (5) grass-spiders live where these injurious worms live: (6) grass-spiders are quite sensitive to chemicals and when they are chemically sprayed, they evacuate promptly. Not a few of them are killed by chemical spray: (7) the existence of spiders' nest does not cause any death of trees and the retard of growth, but may bring about some unfavorable appearance of trees.

Despite the aboves even merits, when we want to apply biological control, the first problem is whether artificial propagation is possible or not. Frankly speaking, propagtion of grass-spiders is quite difficult. In order to get many spiders in a short period, a wide breeding room and large amount of expenses are required. Fortunately, we can find many of grass-spiders everywhere in Japan and thousands of egg-sacks can be collected without difficulty. Since one egg-sack contains several ten eggs, if such egg sacks are put in the damaged area of the previous year or infested trees, the density of grass-spiders can be intensified and the difficulty of artificial propagation is to be solved.

So many worms are fallen down from trees during the larva stage and the reason for this fact so far studied is as follows.

(1) They are fallen down in strong wind or gust. (2) They seem to work more in the night than in the daytime and many of them are fallen down in the night. (3) When the host is changed (when one tree is eaten up and they move to another tree). (4) Young worms on the back of a leaf in group eat the leaf and sometimes they fall down with the leaf. As stated in the above, spiders have relatively many chances to prey upon the worms. However, as previously stated, when a larva becomes over 4 cm, even grass-spiders can not eat them. In this sense, it is considered to breed grass-spiders to be able to prey upon young worms. The writer is of opinion that giving some heat and moisture to egg sack in the room, hatching is speeded up or made late to control worms in the early stage as many as possible. Also the study on large size of grass-spiders may bring great benefit to us.

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Explanation of plate 1

Fig. 1	Experimental mulberry farm
Fig. 2	Nest of grass-spiders (Agelena opulenta)
Fig. 3	Fall-web worms in their attack
Fig. 4	Nest of grass-spiders (Agelena opulenta)
Fig. 5	Nest of grass-spiders (Agelena limbata)
Fig. 6	Larvae of fall-web worms in early stage

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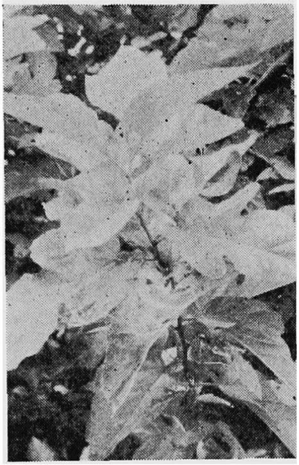
Fig. 1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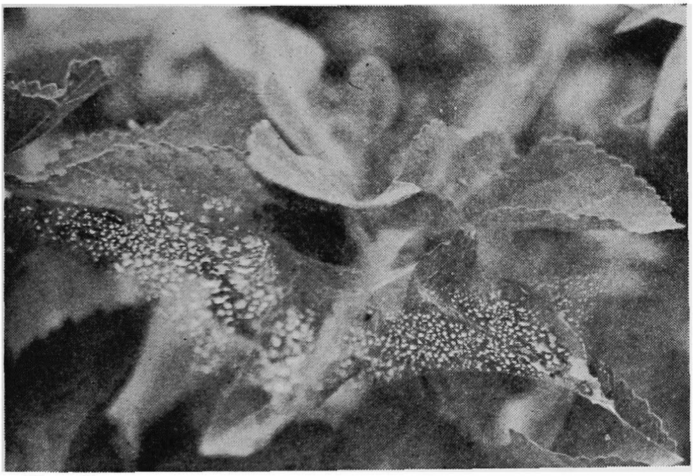
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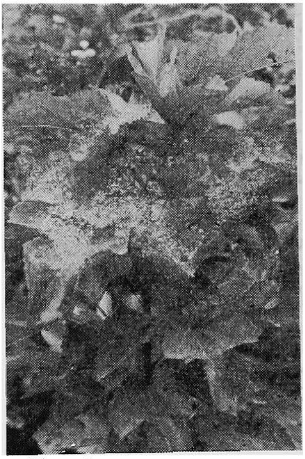
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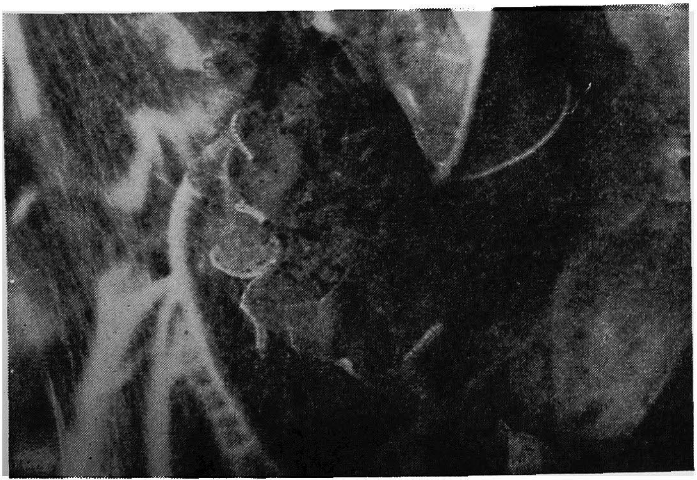
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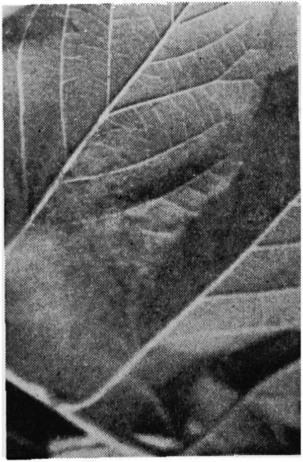
Fig. 6